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*ON THE THEORY OF ORGANIC VARIATION.**

As the evolution question becomes more and more deeply examined the particular phenomena described under the terms variation and heredity are concentrating much closer observation and thought. The whole philosophy of the matter seems to turn upon the interpretation of these phenomena.

* An address delivered before the Philosophical Club of Yale College, April 1, 1897.

In this discussion biologists and those who are engaged in adjusting biological theories to the systems of human thought appear to be resting on the assumption that the great result of the speculations of the last fifty years has been the furnishing of a rational explanation of the so-called natural causes of variation of organisms in their morphological and physiological aspects. This assumption appears to be associated with another, which in some sense is its antithesis, *i. e.*, that those organic phenomena which recur in relatively uniform cycles in successive generations of organisms are fundamental, are the expressions of the intrinsic nature of organic matter, and thus lie beyond the immediate investigation of science. According to this view, heredity (*a*) is not caused, but is a primary law of all organisms; variation (*b*) is a departure from the strict operation of the law of recurrence in generation; and thus external environment (*c*), or the general conditions of being in which organisms exist, is effective in its interaction with the intrinsic energies of the organism in diverting or modifying the natural expression of those energies, to the causing of that diversity and heterogeneity of form and operation which we see about us. This is, as I understand it, a fair expression of the general attitude of thinking men toward the problem in question. This position has received little consideration because it has

been taken for granted as a fundamental truth. It may be tersely expressed in the following form:

1. Heredity is a fundamental law of all organisms.

2. Variation is an acquired law of organism, and is determined by the interaction of the heterogenous environment upon the otherwise uniformly operating organic matter.

It is the validity of these two propositions that I would call in question and discuss. Is heredity acquired? When the attempt is made to state with precision what takes place in the phenomena of organic evolution the question arises: What is the relation which variation bears to heredity as a factor in the case? Which is fundamental; which is acquired?

In order to make the real point of the case clear, let us take an analogy from the field of physics. In astronomical phenomena the planetary bodies are observed to be in rotary motion about the sun and about their own axes; is the rotary motion fundamental or acquired? The first law of Newton is this: "Every body continues in its state of rest, or of uniform motion in a straight line, except in so far as it is compelled by force to change that state." And force is defined as "whatever changes the state of rest or uniform motion of a body." According to these accepted laws of mechanics, rotary motion must be regarded as secondary to direct motion or translation. In order to explain rotary motion, the law of gravity is brought in, and the circular motion is defined as the resultant of the motion of translation adjusted to the gravitation of the masses of matter in motion.

From this analogy the real nature of the problem may be inferred when we ask what is the relation which heredity bears to variation in the field of biology? If it be a fundamental law of organisms to repeat themselves in cycles of generation, to adopt the analogy of mechanics and physics, it is essential to postulate some force to account for any deviation from such hereditary cycles. If, on the other hand, variation be the primary law of organism, the postulated force is required to account for the repetition: such a force would operate first in checking the variation. It will thus be seen that the explanation of the phenomena of life will be greatly modified according as one or other of these hypotheses be assumed to be true.

If we look back over the history of opinions in natural history we discover that a century ago the whole philosophy of organisms was dominated by the Cuvierian notion that species are immutable; *i. e.*, that the cycles of phenomena presented in the development of an individual organism in the passage from the embryo to the adult stages are the same for all members of a species; that this uniformity in expression of development by the individual is the mark or distinguishing characteristic of each species, and therefore that variations, or departures from this fixed law, are accidents due to the disturbing effects of outward environment upon the individual, and cannot be transmitted to offspring by the ordinary laws of heredity. It was this conception of the immutability of species which made 'special creation' of species seem to be a rational theory, and it was the calling in question of the immutability of species which was supposed to limit the capacity of creative force in the universe.

Lamarck advanced the theory that species are not fixed, but are mutable; and he was supposed to be attacking the very foundations of natural history; he was laughed at and his theory was, for the time, silenced by the weight of authority and the common opinion of naturalists. One of the strongest arguments used against his theory was the very fact of species as

they were then known to science. If they are mutable, it was argued, how would it be possible to separate so many which are known as perfectly distinct and not even capable of crossing so as to mix one with another. Sterility was seen to be an impassable barrier distinguishing one species from another, and, as the individuals of one generation are to be accounted for only as descendants of a previous one, how would it be possible to make this barrier on the theory that the law of each species is not fixed and immutable? But although the theory of mutability of species was thought to be absurd a century ago, and was supposed to contradict the fundamental principles of natural history, the idea of specific mutability has now become an established truth in our philosophy of organisms, and variability, or the power of the organism to *divert* from the current paths of development of its ancestors, has become the important factor in evolution. We find, in fact, Bateson, in his elaborate treatise on variation,* saying: "Variation whatever may be its cause, and however it may be limited, is the essential phenomenon of evolution; variation, in fact, is evolution" (p. 6).

When we follow up the history a step further we discover that the theory of mutability of species is built directly upon the Cuvierian philosophy, but it is by breaking down the distinction between varieties and species as originally understood. Lamarck and Darwin both accepted the old conception of the normal or fundamental uniformity of the processes of generation, but, recognizing the fact of departure from this uniformity, assumed that the variation is due to the active adjustment by the organism of its structure to changed conditions of environment (Lamarck); or, the variations being spontaneous or accidental, they are preserved and transmitted in generation from parent to off-spring (Darwin).

Both schools and, so far as I have observed, the great majority of all those who discuss these problems, have started with the assumption that the normal province of what is called by the general name of reproduction is the cyclical repetition of phenomena expressed in the ancestors, *i. e.*, that the phenomena will be alike unless some cause can be discovered for their dissimilarity. Hence to discover the cause of differences has been the chief purpose of observers and speculators.

Darwin's ideas regarding the nature of variability in organism are clearly set forth in his 'Origin of Species.' In the first chapter on 'Variation under Domestication,' under the general title 'Causes of Variability,' we find this significant sentence: "It seems pretty clear that organic beings must be exposed during several generations to the new conditions of life to cause any appreciable amount of variation, and that when the organization has once begun to vary it generally continues to vary for generations" (p. 14). A few sentences further on are these words: "It has been disputed at what period of life the causes of variability act," and "I am strongly inclined to suspect that the most frequent cause of variability may be attributed to the male and female reproductive elements having been affected prior to the act of conception," and again: "When any deviation of structure often appears, and we see it in the father and child, we cannot tell whether it may not be due to the same cause having acted on both" (p. 19). Again in the chapter on 'Laws of Variation:' "Nevertheless, we can, here and there, dimly catch a faint ray of light, and we may feel sure that there must be some cause for each deviation of structure, however slight"

*Materials for the study of variation treated with special regard to discontinuity in the origin of species, by Wm. Bateson. 1894.

(p. 121). And the closing sentence of this chapter : "Whatever the cause may be of each slight difference in the offspring from their parents, and a cause for each must exist, it is the steady accumulation, through natural selection, of such differences, when beneficial to the individual, that gives rise to all the more important modifications of structure by which the innumerable beings on the face of this earth are enabled to struggle with each other, and the best adapted to survive" (p. 153).

I quote thus freely from this standard author and classic treatise on evolution, in order that we may see what the assumption in the case actually is, and also to show that it is a fundamental assumption at the very foundation of the current philosophy of evolution. The quotations are sufficient to show that it was assumed that particular variations are particularly caused, *i. e.*, while variability may be regarded as the possibility of varying, or the latent capability to vary, each variety was, by Darwin, considered to be caused by a special something with which the organism comes into relation and which did not operate upon its ancestors.

I do not propose here to discuss the metaphysical question as to whether an organism may or may not be said to possess powers or potencies, properties or capabilities, or whether it is necessary or not to assume that an organism is capable of varying before it does vary. But in this paper attention is called to the relation which a certain class of biological phenomena bear to another class of biological phenomena, and, so far as it may be possible to confine one's attention to them, these phenomena alone will be considered. From this point of view variation is a deviation, in the order of sequence, of one series of phenomena from some other order of sequence with which it is compared. In the case of organisms the latter series of phenomena is that which the parent form (A) exhibits in the course of its growth from the ovum to maturity. The case we compare with it is the series of phenomena expressed by an offspring (B) in passing from the ovum to the mature stage. A variation occurs whenever, in any particular stage of the series, B varies or deviates from the series A. Supposing such a deviation to take place the morphological character (v) expressed in the structure of the organism (B) is often and may properly be called a variation. The whole organism B, with its added character (v), is often spoken of in biology as a variety of A, and all descendants of A exhibiting the variation (v) are said to be of this variety (Bv). As I understand the Darwinian doctrine (and I believe this is the generally accepted doctrine on this point) it is assumed that except for some special cause acting upon the organism A, or its ancestors for each particular variation (v) of this kind, there would appear no deviation in B, there would arise no variety Bv. Let us be careful not to raise the question whether the organism could vary or could not; the question is purely regarding the order of the phenomena. It is a question of science as to whether the variation takes place on account of some cause (I use the word used by Darwin and suppose we may infer that he means some interference with the course of phenomena taking place in the developing organism), and I raise the question : Have we any evidence to support the opinion that variations would not occur except for some such interference with the normal processes of development exhibited by the growing individual?

If we examine Professor Cope's 'Primary Factors of Organic Evolution,' standing, as it does, for the most extreme of the Neo-Lamarckian school of naturalists as contrasted with the Darwinian, we find a similar assumption on this point. Cope divides

his treatise into three parts, which he enentitles: I. The Nature of Variation; II. The Causes of Variation; III. The Inheritance of Variation. He begins the Part III. by saying that he proposes to cite "examples of the direct modifying effect of external influences on the character of individual animals and plants. These influences fall naturally into two classes, viz., the physico-chemical (molecular) and the mechanical (molar). The modifications so presented are supposed to be the result of the action of the causes in question, continued throughout geological time" (p. 225). A few of the examples cited are the conversion of *Artemia salina*, a salt-water Crustacean into a *Branchinecta*, a genus accustomed to fresh-water habits; the production of colors in Lepidopterous pupæ; light and feeding affecting the color of fish; the case of the blindness of cave animals; Dr. Dall's theory of the origin of plaits in the Gastropoda; the moulding the shape of the articulation of bones in accordance with the dominant strain put upon them; the mechanical origin of dental types in Vertebrates.

No question is here raised as to the reality of the observed phenomena; the association of particular modifications of organic structure with change in the conditions of environment to which the organisms are subjected is not disputed. But the specific question raised is this: Does environment in general, or do the external influences of a chemico-physical or mechanical nature (to use Cope's phrases), exert an influence over growing organisms to induce them *to depart from* the order of phenomena of their ancestors, or do these influences or forces produce the opposite effect of *controlling and limiting* variation? From the quotations it will be evident that the theory is clearly expressed in the writing of the two prominent schools of evolution of to-day that *these external influences do, either directly or indirectly, produce the variations.*

Several years ago my studies led me to doubt the validity of this view, and a careful study of the order of sequence shown in the succession of species in geological time has confirmed this opinion. My friend and former neighbor, Professor Bailey, of Cornell, a pupil and ardent disciple of Asa Gray, has been led to the same conclusion from the study of plants, and he has supported and given botanical evidence for the validity of the theory in this book on 'The survival of the unlike' (Macmillan, 1896, see p. 21, 22). I also presented some evidence of paleontological nature which seems to support the view ('Geological Biology,' 1894'). The present paper is intended to consider the philosophical line of reasoning upon which the theory rests.

The commonly held conception seems to be that variation, and consequently the essential essence of evolution, is some kind of modification of ordinary generation. So much is this true that in most minds and in standard treatises on evolution the two words development and evolution are used as synonymous terms.

We may then resolve the question into this concrete form: In the case of any particular organic cycles of phenomena, is it more simple and fundamental for the organism to reproduce its kind or to produce itself, *i. e.*, its mature self from the germ? We can logically find but one reply to this question. Production must precede reproduction. But what does this answer imply? It implies that the processes of development of the individual from the germ to the adult do, in their intrinsic nature, precede the phenomena of reproduction. It further implies that the phenomena of evolutional variation are supplementary to, and then a further pushing on of, the phenomena of individual development. The assumption, which is generally accepted, appears to be that this mode of variation is a modification of ordinary reproduction, either produced

by some spontaneous action of the organism, or the result of the influence of changing environment upon the organism. For, in speaking of variation, it is customary to say that the variation becomes fixed by selection, or becomes transmitted, as if the disturbance in the order of the phenomena, which at first entered as an accident, became, by some means, an added part of the normal cycle of development of succeeding generations.

We hear such expressions as that it is impossible that a variation can be transmitted till it affects the germ-plasm, or till the variation becomes a variation of the reproducing, as distinct from the somatic, part of the individual. This conveys the impression that that which varies is the reproductive cycle of phenomena, whereas the truth is more accurately expressed by saying that the reproduction cycle is augmented. The augmentation in the case consisting of an extension of the process of growth of the individual beyond the point reached by the ancestor, the process is, first, purely of the nature of the building up of tissue and structure, and is not reproduction, but simple production, the process of production going beyond the extent or limit reached by the ancestors.

The confusion arises from not distinguishing the phenomena by which the structure of the individual is perfected from other phenomena by which a new individual becomes separated from the old and begins, carries on and repeats the previous cycle of phenomena. That phenomenon which is the first step of every evolutional process, as well as every step by which evolutional progress is accomplished, is fundamentally a growth phenomenon, quite of the same nature as the growth taking place throughout the life of each individual. It differs from these normal growth phenomena only by exceeding in some particular, or deviating in some manner, from the cycle of growth phenomena of the ancestors. Evolution does not call for any augmentation of the phenomena of reproduction.

If we separate the processes of (1) the growth or development of one individual from (2) the reproduction of a separate second individual we discover that the development of the first individual must necessarily have been carried to a certain point of completion before the reproduction of a germ takes place, since it is the more or less mature individual which reproduces the germ. When, further, we compare with these two processes the further phenomenon of variation which results in evolution we find that the variation does not belong to the reproduction, but to the development of the individual. Variation is a transcending the course of development of its ancestor by the offspring ; reproduction of the variation is not variation, but a repetition of a previous course of development. It is simply a continuation of those processes which have been going on in the individual and are regarded by the observer as perfectly normal up to the point of reproducing the features of the ancestor, but are looked upon as abnormal so soon as they transcend their limits.

Inquiry into what we mean by normal and abnormal will reveal the commonly received doctrine in the case. By normal we mean according to the steps of growth of the ancestor ; that is to say, the assumption is made that it is natural or normal for reproduction to proceed in some path already traversed. Now, in fact, this is not strictly true; first, we know that species are constantly showing departure or 'abnormal' growth (using abnormal in the above sense), and the deviation is called variation; and secondly, we have reason to believe that organisms never proceed in exact imitation of anything else, that every part of every organism is in some infini-

tesimal sense different from any other. This is really a distinctive feature of organisms as contrasted with bodies of inorganic matter.

This distinction between normal and abnormal reproduction, as if variation were but a slight modification of the so-called law of reproduction, has also led us into confusion. Reproduction is but the production again of what has been produced in a previous cycle; and a case of variation in the offspring, however slight, is not a case of reproduction, but of the production in the offspring of some new character, and the great thing to account for is the fact of the production of such new characters in organisms. But the process by which the individual acquired some new character is not different in nature from the process by which it acquired the old characters already expressed by its ancestors. If we can account for growth in the first place we are on the immediate track of accounting for the continuance of growth. To say that the growth of the individual in a particular direction and to a particular degree is due to the influence of the ancestor upon the offspring is offering a cause for reproduction, but not for variation; for, however variable the original stock might be, generation would result in increasing the degree of uniformity of the ancestry of each individual. As one can easily discover by computing the total number of direct ancestors of any individual with two parents, and supposing them to belong to distinct lines in each generation, it would take but twenty-one generations back to find one's lineage spreading over a million separate individuals of the twenty-first generation. If the ancestors controlled the growth of the offspring it is thus evident that, however different might be the individuals at any particular period in the course of a hundred generations, given free access to crossing, each offspring would unite strains of influence from every possible line of ancestry which had been accessible.

If variation were the result of difference in the external conditions, or what we call environment, the question arises why should not the same variability be expressed in the phenomena of crystallization; in the phenomena of chemical combination of elements; in the phenomena of light or heat, and in all the physico-chemical phenomena of matter, where like conditions produce like effects? If we have a uniform common force at work, the varying expressions of which are due to diverse conditions of environment, why should the result be so different from any other uniform common force operating under like diverse conditions of environment? The question brings its self-evident answer; the variations cannot be explained as the reflex of a discrete and varying environment upon a uniform common kind of matter. The idea that the cycles of development of the offspring should repeat the cycles of development of the ancestors is based on the prior assumption that the organism does not normally vary; that it acts as if it were an inorganic body, subject to the law of inertia and conservation of force. With this idea, it is easy to imagine that the cycle, once started, should not stop, except by reason of some resistance or impediment.

But we ask how can the cycle begin? How can it be started? and here we come to the fundamental point under consideration. Starting is itself variation—a departure from remaining inactive; and a cycle is uniformity, not variation. If the simplest act in the world takes place, it is a diversion from the condition of things before it took place; and if it stop and is simply repeated periodically, there is a cessation of the action of the initial starting force, and we have but the continuation of reflex action of the original impulse in the midst of resisting media. Hence, to begin

a cycle of phenomena, of whatever kind, requires the initiation of the original variation in which it began. The same is true of any variation thereafter, if we are to apply the reasoning which is valid regarding physico-chemical laws of matter to the phenomena of organisms. If the variation be primitive, and normal, to use the word in the sense proposed, it is evident that what we call reproduction is but a pulsation of the phenomena of life itself, recurring in the precise cycles which express the equilibrium between a definite quantitative force in the individual organism itself and the definite quantitative forces of the total environment in which it carries on its life functions.

The preservation and perpetuation of derived characteristics in a race seem at first sight to be easily accounted for by the process which Darwin has called natural selection. Variation, in this hypothesis, is supposed to occur 'naturally,' by accident, or, as Darwin says, 'spontaneously.' But a close examination of what such a proposition would mean in concrete facts reveals serious difficulties. The apparent simplicity arises from the assumption that the law of hereditary transmission of ancestral characters is a primary law of organism, which is violated in every case of variation. On such an assumption we have only to conceive of the removal of whatever may have occasioned the accidental or spontaneous disturbance in order to permit the continuing on of the normal working of heredity. But when we follow the hypothesis back to its beginning, it provides no means for rising from the original level of simplicity. Each variation must, according to the theory, be a violation of the normal action of the organism; hence if the organism were adjusted when the variation took place the variation puts it out of adjustment, and we have no place for the action of natural selection. If, on the other hand, the variation is advantageous to the economy of the organism, then we must assume either that the organism was not in perfect adjustment when it varied; and then again the adjustment is accounted for without the action of natural selection, or else the lack of adjustment came from change of conditions. In this case the conditions of environment, not natural selection, account for the adjustment. And there seems to be a still greater difficulty, viz., the extreme length of time necessary to bring about the changes that have taken place by the process. Recently Professor Poulton called attention to the necessity of this great time period (longer than the physicists or geologists are generally ready to allow to have been possible), in order to account for the results we find recorded in the fossil-bearing rocks, requiring at least 400 millions of years for the work of evolution.* But Mr. Poulton does not exaggerate the matter.

Let us examine this time factor and see if we can imagine it to have been long enough. In the first place, if hereditary repetition be the normal law of organism, then Professor Poulton has made a fair estimate of the ages it would take according to the present rate of evolution. But he has not taken into account all the necessities of the theory, two of which must be these: First, if the exact hereditary transmission and repetition be the fundamental law of organisms, not only must the progress produced by any mode of variation have been exceedingly slow—at first at a rate decreasing geometrically in proportion to the greater simplicity of the organism; but second, the theory requires that if natural selection consists in making variations permanent, the general progress must take place by means of a process which in every particular case consists in stopping the very phenomena by which the progress is at-

*SCIENCE, Vol. 54, p, 504.

tained. It is, moreover, this becoming permanent, by hereditary acquirement of the variation, which constitutes the evolutional progress of the series. And the difficulty we meet with is that we are assuming that natural selection must actually check, or even stop that variational activity by means of which any change whatever is attained, according to the theory of a primitive law of heredity. But if we were to grant that progress could be attained in this way, and allowing the slow rate of the actual process by which a variety becomes permanent enough to be called a strain or set habit of a race, and granting Professor Poulton's demand of the necessary four hundreds of millions of years for the process at the present rate—granting all this to be possible, we have still to reckon with a still more important process, the raising of the functional importance of the new varietal modification to reach a rank of specific, generic, family, ordinal, and, before we are through with it, class, branch and subkingdom value in the individual economy. The time required for this would be practically infinite. Because, with each step in advance in taxonomic rank and importance, the rigidity of transmission must be supposed to become greater, and thus the degree of possible variability diminishingly less. This would result, even if we were to grant that the change in taxonomic rank of the character be a fact.

But the evidences of paleontology go to disprove the very matter of fact. As has been already pointed out in another place, the degree of differentiation and the classification of invertebrates of the first great era in which we have definite records of organic life are so closely in conformity with that which we know of the invertebrates of the same classes now living that all the distinctions necessary to be considered in an ordinary course of lectures to a class of students in invertebrate zoology, to-day, would apply, so far as the facts are recorded, to the organisms which lived in the earliest period of which we have definite record of any living organism on the face of the earth (' Geological Biology,' p. 212). This evidence means that the same kind of characters, which are varietal and specific characters in living organisms to-day, were varietal and specific characters in the representatives of the same classes back in the Cambrian time; that the same kind of characters which are now generic in rank were then generic characters. And, so, in the case of family, ordinal and class characters we discover no trace of evidence that characters bearing a particular rank in the organic economy now, among living beings, did not always bear the same relative position among the characters of the bodies of their ancestors.

Attention was called to these facts several years ago and their validity does not appear to have been questioned. We observe, further, that in Cambrian time the differentiations of animals of branch value had already taken place, with the exception of vertebrates; and vertebrates appeared in the Ordovicean. And in the case of the vertebrates of the Ordovicean (and only a single locality for them is as yet known) their representatives are distributed by experts into three of the five known (*i. e.*, in fossil condition) sub-classes of Fishes. Fishes, it must be observed, include the type of vertebrates which are adjusted alone to an aqueous environment, and, therefore, we may conclude that, so far as the vertebrates of the environment of which we have any record for that era are concerned, they had reached over one-half the differentiation of sub-class rank ever attained by them.

Lest there should appear to be a misrepresentation of the opinions against which these arguments are directed, quotation from Darwin's ' Origin of Species ' on

this point may appropriately be inserted here.

Darwin wrote:

"Hence I look at individual differences, though of small interest to the systematist, as of high importance for us, as being the first step toward such slight varieties as are barely thought worth recording in works on natural history. And I look at varieties which are in any degree more distinct and permanent as steps leading to more strongly marked and more permanent varieties; and at these latter as leading to sub-species and to species. * * * I attribute the passage of a variety from the state in which it differs very slightly from its parent to one in which it differs more, to the action of natural selection in accumulating difference of structure in certain definite directions. Hence I believe a well-marked variety may be justly called an incipient species (p. 53).

"Therefore, during the modification of the descendants of any one species, and during the incessant struggle of all species to increase in numbers, the more diversified their descendants become, the better will be their chance of succeeding in the battle of life. Thus the small differences distinguishing the varieties of the same species will steadily tend to increase till they come to equal the greater difference between species of the same genus, or even of distinct genera (p. 117).

"Natural selection acts, as we have seen, exclusively by the preservation and accumulation of variations, which are beneficial under the organic and inorganic conditions of life to which each creature is at each successive period exposed" (p. 117).

As if to make the inadequacy of this conception more apparent, we have but to look back across the geological ages, or, accepting the law of recapitulation, to trace the embryonic development of a single higher animal, in order to discover that the earlier differentiations were of actually higher rank, and that as time has progressed the new forms of organisms have been restricted to modifications of less and less importance. The earlier in time we go the more fundamental were the variations which took place, and it is in later geological times that there has come to be more and more rigid adherence to the law of heredity.

The proposed theory of original variability is not only consistent with such a series of events, but they would be the natural expression of such a force in operation. Variability should be most active and most vigorous before the laws of heredity had restricted its action. We must not, however, confuse activity of the operation of this law with multiplicity or complexity of activities in a common body. Complexity of structure is a matter of development and adjustment of the body itself, and much collateral evolution would be necessary before it would be possible for great complexity in a single body to be consistent with the limits of its vital functions. That the changes and adjustments would be great and rapid in proportion to those that followed when the adjustments had become close and involved is, however, evident. Hence it would be consistent to expect rapid evolution at first, gradually decreasing in rate with advance of time, as paleontology teaches us to believe was the actual fact of the case.

The difficulty in the commonly accepted view, it seems to the author, arises from mental confusion rather than neglect of the real phenomenon in the case. The mental juggling takes place when we speak of varieties or variation becoming more permanent, or when we speak of the preservation and accumulation of variations.

Variation as an act means becoming different, but variation as a thing means

something which does not vary. Permanent as an adjective means lasting and enduring, and thus it is contrasted with the adjective sense of the term variable. Thus when Darwin speaks of natural selection as acting by the 'preservation and accumulation of variations,' there is nothing variable in that which is conceived of as being preserved and accumulated. It is a character or morphological structure which is preserved and accumulated in the offspring only when it is the same character which appeared in the parent form. It is the fact of the reappearance of the same character in the offspring which is meant by its preservation. It will be seen, thus, that the origin, or arrival into the organic structure, of the particular concrete variation which, in any particular case, is transmitted and preserved must necessarily have taken place before natural selection acts in that particular case. Therefore, the variation, as an act, or the actual becoming different, is of a two-fold nature: (1) It consists, first, of the growth of some part of the structure of the organism in some way and degree differently from the growth of the same part in the ancestor; and (2), secondly, there is the reproduction of that difference in the offspring in accordance with the growth as it took place in the parent or immediate ancestor. Here, in the act, we see again a confusion of two acts, one of which is permanent and the other variable. The first act is a diversion or contradiction of the law of heredity, the second act is in conformity with it. The true variation, as an act, is thus a real departure, or diversion, from the phenomena of hereditary repetition. It is this which I understand Darwin assumed to have been spontaneous or constantly occurring, and it is the operation of natural selection, chiefly, and of other agencies working upon the living organisms, which, according to Darwin, results in the increasing diversity of the individuals. We are thus led by an analysis of Darwin's own theory to find that the real variations occur prior to any of those operations of the organism, or of the environment, commonly supposed to have caused them.

Darwin's theory, nevertheless, is readily adjusted to the conception of the fundamental nature of organic variation here proposed. It requires but an expansion of the idea of mutability of species so as to include mutability of the individual and of organic matter itself. Natural selection is constantly producing heredity, not variation. But natural selection is not the only cause; environment in general, and we might extend the idea of environment and say that experience is constantly resulting in the hereditary transmission of qualities or characteristics from parent to offspring.

The definite laws of heredity for any particular organism at any particular point in its history are but the recapitulation of the experience of its ancestors in overcoming, conquering and using for their enrichment the impediments and constantly acting hindrances to their living and existence. Varying is the first, as it is the last, performance of the living being. Invariability is the law of the inorganic world, but is the sign of death among organisms. This thought was aptly expressed by the late James D. Dana, in the last revision of his 'Manual of Geology.' Speaking of variation among organisms he wrote: "It is perceived that the law of nature here exemplified is not 'like produces like,' but like *with an increment* or some addition to the variation. Consequently, the law of nature, as regards the kingdoms of life is not permanence, but change, evolution" (p. 1033).

A rational and consistent conception of organic evolution arises from this theory of the fundamental nature of variation in organisms. Evolution is, to this theory, only the extension of the phenomena of

growth, or development of the individual beyond the point reached by its ancestors. Natural selection operates in the manner set forth in the current hypothesis, only the result is confined to holding in check and regulating the cycles of individual development, not to producing them. Environment affects the organism, both directly and indirectly, as Lamarck and the Neo-Lamarckians claim, but the effect is in the way of checking and then controlling variation.

The organism is in all respects dependent for its resources upon environment. Living is a constant process of occupying, using and discarding matter, and therefore any structure or function developed by the organic body is either profitable to the continuance of the living individual, or it is not profitable. Any modification of structure has a definite economic value to the individual; if its benefit does not equal its cost in energy its production is an unprofitable venture and is either not repeated or the individual is crippled and finally lost by the operation of natural selection. If the organism, for any cause, acquires surplus energy it is expressed in variation, and if the variation is to the advantage of the individual, *i. e.*, if the resources of new energy resulting from its presence exceed the expenditure for its construction and maintenance, the result is beneficial and the new structure is retained and a step in advance is made.

Thus the condition of environment, from the old point of view, seems to cause the organism to vary; in the new view, the organism adjusts and keeps adjusted to its environment by the law of internal economy, not by the external struggle for life.

It is not necessary, here, to suppose that there must be a specific conscious adjuster residing in each organism. We do not find it necessary to imagine a specific *erdgeist* in order to cause the earth to follow the intricate curve of its revolution among the other planets and about the sun. Nor is it necessary to assume, as Professor Bailey puts it, that "definite variation is an inherent or necessary quality of organic matter,"* but given this general law of variation as an intrinsic property or mode of operation of every particle of living matter, and the phenomena of life will result—in the lowest stage as metabolic phenomena, then in the second stage as individual development and, also, in the third stage as evolution, by simply continuing their activities. And the same power which can constitute variation among the phenomena of matter, otherwise controlled by the inflexible physical laws of inertia and conservation of force, can, doubtless, institute in living matter that still higher function, consciousness, with all the wonderful phenomena which are associated with it.

The significance of this theory is considerable, both scientifically and philosophically. From a scientific point of view, variation or variability is recognized as the very essence of the vital phenomena, as gravitation is recognized as an essential characteristic of matter. Life is as remarkable (but perhaps no more so) as that sudden demonstration of expansion which inelastic water or rigid ice exhibits when raised to 212 degrees of Fahrenheit. We might study ice and water for eternity under temperatures below the boiling point and never discover the properties of steam So, whether the vital phenomena are latent in matter or not is a matter of speculation. Whenever vital phenomena appeared they appeared in phenomena exhibited by matter. Whenever inorganic matter becomes vitalized, however that result may be accomplished, variation takes place and distinguishes it from matter in every other condition.

*'The Survival of the Unlike,' p. 22.

If anything be evolved by evolution it is evident that, whatever its nature may be, it must cease to be evolved if it would maintain its integrity. For inertia of matter and conservation of force apply to bodies which no longer are undergoing evolution. Variation, as a process of becoming different, is a characteristic of living bodies, and, though it is not doubted that in the phenomena of variation it is ordinary chemical and physical matter which exhibits the peculiar vital phenomena, we have no reason to suppose that the operations of physics and chemistry are thus variable.

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MICROSCOPICAL EXAMINATION OF WATER, WITH A DESCRIPTION OF A SIMPLE FORM OF APPARATUS.

THE microscopical examination of water is becoming every year a matter of greater interest, and the study of the minute aquatic plants and animals is more and more attracting the attention of scientists. These organisms are interesting for several reasons and, besides recognizing their importance in the domain of pure science, we are beginning to appreciate the great part that they play in nature and their effect, direct and indirect, upon the human being. Their presence in surface waters is often the cause of much harm when the water is used for purposes of domestic supply; scores of instances may be mentioned where they have rendered the water entirely unfit for use. On the other hand, their presence in ponds and streams is of importance to the fish-culturist because they form the fundamental source of the food supply of fishes; this is probably true both of salt and fresh water.

Because of this connection between the number of microscopical organisms in a cubic centimeter of water and the price of fish in our markets, the study of the 'plankton,' *i. e.*, the floating micro-organisms, is being emphasized on both sides of the Atlantic. Observers are beginning to trace the connection between the presence of microscopical organisms and the abundance of fish in our lakes, and valuable comparisons have been made between the stomach and intestinal contents of fishes and the organisms found in the water where the catches were made. This work is of very great importance and should be vigorously pursued by our fish commissions. To be of the greatest value it should extend well over the country and include lakes and ponds sufficiently different in character to enable one to determine the laws governing the nature and distribution of the plankton in various climates and under various conditions. The study ought not to be carried on spasmodically, as, for instance, during the short vacation of some college professor who generously gives his time and talents to the cause, but should be undertaken seriously and continued throughout the whole year. Only in this way can we obtain the data necessary for a complete understanding of the subject.

Since water works managers are equally interested in the microscopical organisms found in surface waters, and up to the present time have been responsible for most of the work done upon the subject, it might be possible for fish commissions, boards of health, water-works superintendents, and others interested, to work together according to a definite concerted plan, sending their results to some central commission or committee for comparison and study. Such an extended biological study taken in connection with meteorological records and observations upon the temperature, transparency, etc., of the water would be of very great value. And it would seem that we have little excuse for neglecting to cultivate this fruitful field of research. Vast num-